APPENDIX 8-B. MAINTENANCE & REPAIR COST DETERMINATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 8-B. MAINTENANCE & REPAIR COST DETERMINATION

8-B.1 INTRODUCTION

The maintenance cost is the price of regular scheduled product maintenance ($/year). The repair cost is the price to repair the product when it fails ($). These costs cover all labor and material costs associated with the maintenance or repair of existing products. The calculation of the repair cost involves determining the cost and the service life of the components that are likely to fail and includes the labor and the materials associated with the replacement.

Many maintenance and repair costs are estimated using cost tables similar to the ones used in RS Means.[1, 2] Figure 8-B.1.1 shows the methodology for calculating maintenance and repair costs and Table 8-B.1.1 offers an example of maintenance/repair cost calculation. All labor costs are derived using the latest RS Means labor costs by crew type.[2] All repair and maintenance cost tables include a trip charge which is often charged by contractors and calculated to be equal to one half hour of labor per crew member.[2] Labor hours (or person-hours) are based on RS Means data, expert data, or engineering judgment. Bare Costs are all the costs without any markups. Material costs are based on RS Means data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RS Means.[1, 2] Labor cost factors are calculated for each census division and four large state (see appendix 8-A for details). Values reported in this appendix are based on national average labor costs.

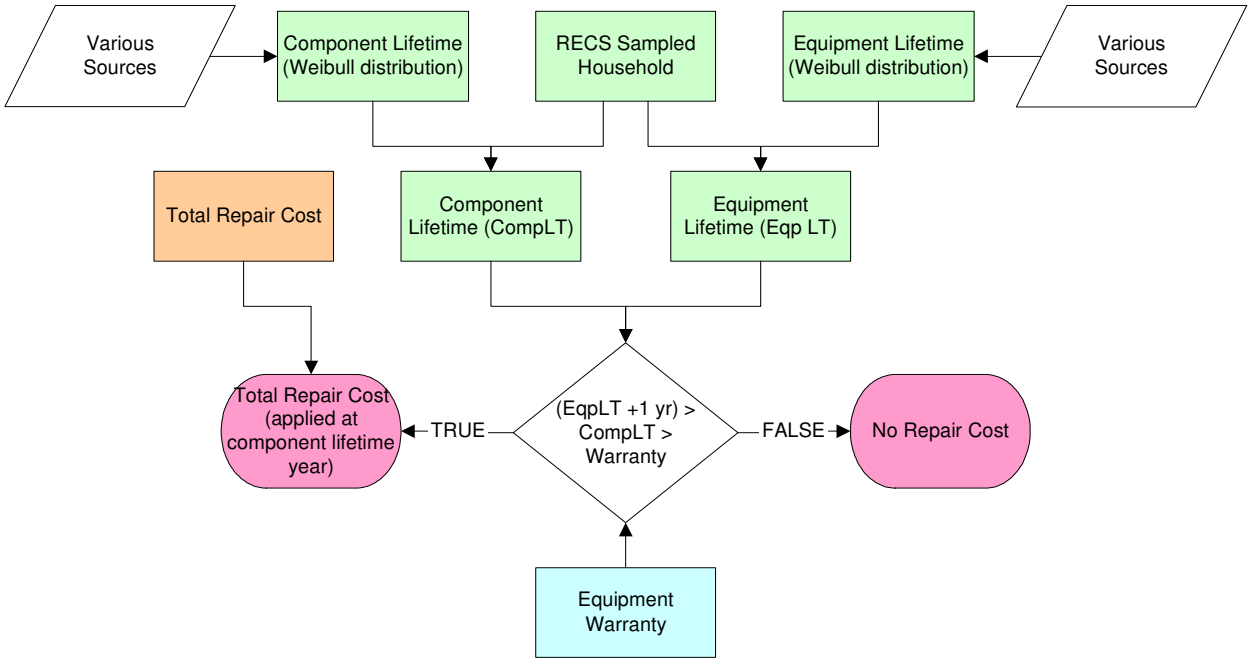

Figure 8-B.1.1 Methodology for Calculating Maintenance and Repair Costs

Table 8-B.1.1 Example Maintenance/Repair Cost Table

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	CREW1	0.5	0.00	23.00	0.00	23.00	35.00
Description of Maintenance or Repair	CREW1	0.5	0.00	23.00	0.00	23.00	35.00
Total		1.0	0.00	47.00	0.00	47.00	**70.00**

The determination of the repair cost also involves determining the service life of the components that are likely to fail and comparing it to the lifetime of the product. Figure 8-B.1.2 shows the methodology for determining repair costs for an individual sampled household. Both component and equipment lifetimes are given by Weibull distributions. During the lifetime of the equipment only a fraction of the sampled households will see a repair cost. Repair lifetime distribution derivations are explained in section 0.

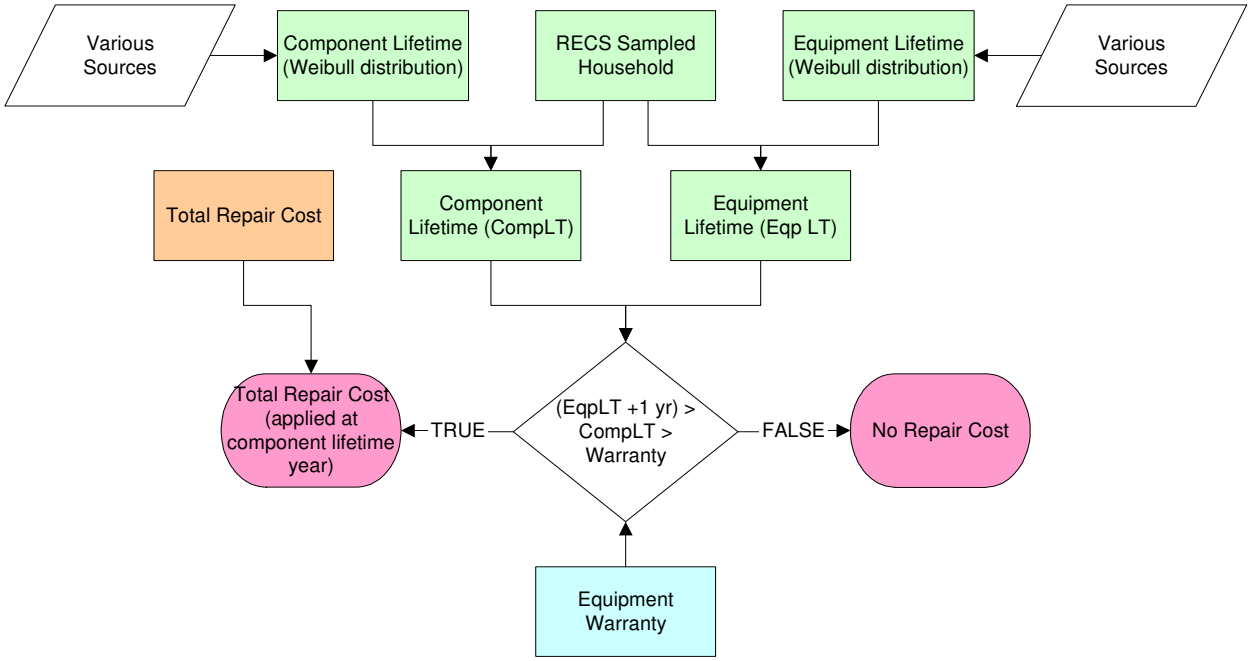

Figure 8-B.1.2 Methodology for Determining Repair Cost for a Sampled Household

8-B.2 MAINTENANCE COSTS

DOE included maintenance costs for all heating products. This section outlines the maintenance costs determined for each product class.

8-B.2.1 Gas-Fired Storage Water Heaters

DOE included maintenance cost for gas-fired water heaters. Manufacturers recommend that water heaters be drained and flushed annually to minimize deposition of sediment, maintain operating efficiency, and prolong product life. The available evidence indicates that this practice

is done in 10 percent of households, and mostly in locations with hard water.[3] DOE assumed that, of this 10 percent, only 25 percent of consumers hire a contractor to perform the maintenance work. For this maintenance cost, the labor hours are determined from a consultant's report.[3] The labor cost is based on RS Means.[1, 2] The total cost is $111 per year and is applicable to 2.5 percent of installations.

Table 8-B.2.1 Gas-Fired Storage Water Heater Draining and Flushing

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	0.00	24.68	0.00	24.68	37.04
Drain and fill tank	1 PLUM	1.0	0.00	49.35	0.00	49.35	74.07
Total		1.5	0.00	74.03	0.00	74.03	**111.11**

* 1 PLUM means a crew of 1 plumber.

In addition, all new gas-fired storage water heaters are equipped with Flammable Vapor Ignition Resistant (FVIR), which manufacturers recommend be maintained annually. The available evidence indicates that 25 percent of households are likely to hire a contractor to perform this work.[4] For this maintenance cost, the labor hours are determined from a consultant's report.[3] The labor cost is based on RS Means.[1, 2] The total cost is $148 per year and is applicable to 25 percent of installations.

Table 8-B.2.2 Gas-Fired Storage Water Heater FVIR Maintenance

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	0.00	24.68	0.00	24.68	37.04
FVIR Maintenance	1 PLUM	1.5	0.00	74.03	0.00	74.03	111.11
Total		2.0	0.00	98.71	0.00	98.71	**148.15**

* 1 PLUM means a crew of 1 plumber.

8-B.2.2 Electric Storage Water Heaters

Manufacturers recommend that electric storage water heaters be drained and flushed annually to minimize deposition of sediment, maintain operating efficiency, and prolong product life. The available evidence indicates that this practice is done in 10 percent of households, mostly in locations with hard water.[3] DOE assumed that of this 10 percent fraction only 25 percent hire a contractor to do the maintenance work. For this maintenance cost, labor hours and costs are based on RS Means[1, 2] and are equal to $105 per year for 2.5 percent of the installations.

Table 8-B.2.3 Electric Storage Water Heater Draining and Flushing

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	0.00	23.35	0.00	23.35	35.05
Drain and fill tank	1 PLUM	1.0	0.00	46.70	0.00	46.70	70.10
Total		1.5	0.00	70.05	0.00	70.05	**105.15**

* 1 PLUM means a crew of 1 plumber.

DOE determined that there is virtually no maintenance of electric resistance water heaters. For heat pump water heaters, maintenance includes annual cleaning of the air filter and a preventative maintenance cost to check the evaporator and refrigeration system. The literature recommends that no professional help is needed for this maintenance.[5, 6] DOE believes there are instances in which such help is needed; thus, for certain heat pump water heater installations it added a preventative maintenance cost to check the evaporator and refrigeration system. For locations where the HPWH might be more exposed to the outdoor environment, such as garages and crawlspaces, DOE applied a 5-year preventative maintenance cost based on Australian HPWH outdoor installations.[7, 8] DOE estimated that 27 percent of these exposed installations would require this maintenance, based on a survey conducted for central air conditioners.[9] For heat pump water heaters that are located indoors or in basements, the maintenance requirements are considered to be the same as other similar indoor appliances such as refrigerators and room heaters, which don't have any additional maintenance costs [10, 11] For this maintenance cost, DOE based the labor hours and costs on RS Means.[1, 2] The total cost is $81 per year and is applicable to 27 percent of installations.

Table 8-B.2.4 Heat Pump Water Heater Maintenance

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.500	0.00	23.35	0.00	23.35	35.05
Clean evaporator, drain pan, drip pan	1 PLUM	0.652	0.00	30.45	0.00	30.45	45.70
Total		1.152	0.00	53.80	0.00	53.80	**80.75**

* 1 PLUM means a crew of 1 plumber.

8-B.2.3 Oil-Fired Storage Water Heaters

Oil-fired storage water heaters and burners are cleaned and maintained regularly. Maintenance is most frequently performed under annual maintenance contracts, which typically includes repair of failed components. The maintenance contracts apply to all energy efficiency levels and no separate repair cost was included.

To derive the cost of the maintenance contract for water heaters DOE collected maintenance contract prices gathered from web sites which represent oil-fired product suppliers in the eastern U.S (see Table 8-B.2.5). This cost varies widely, depending on the presence of other oil-fired products in the residence. The maintenance cost of the oil-fired water heater is usually an additional cost added to the total oil-fired equipment contract. Costs may go down if

multiple oil-fired appliances in a household are on the same contract. DOE estimated the average cost of the oil-fired storage water heater maintenance contract by including half of the average cost of the oil equipment contract and the average cost for the water heater contract option.

Table 8-B.2.5 Maintenance Contract Data Table

Company	Location	Description	Cost of Oil Eqp Contract *(2008$)*	Cost of WH Option *(2008$)*
Brennan Oil	RI, MA	Oil Rite Plan	$175.00	$75.00
Noonan Energy	MA	Basic Plan	$109.95	$35.00
Heritage Energy	NY	Traditional Home Oil Plan	$189.95	$119.95
Hi-Ho Petroleum	CT	Main Burner	$185.00	$85.00
Drum Oil & Propane	NY	Oil Heating System - Plan A	$184.95	$94.95
Richard T. Layton Co.	CT	Oil Burner Service Contract	$164.95	--
Stadium Oil Heat	MA	Service Contract	$169.00	$50.00
Williams Service Company	PA	Oil Hot Water Heater Service Plan	--	$91.95
Solliday Oil Company	MD	Certified Comfort Plan #1	$125.00	--
Slomin's	NY, VA	Econo Pak	$99.00	$26.95
Springbrook Ice & Fuel Service	CT		$180.00	--
Warthen Fuel	MD	PLAN B - Standard Maintenance Agreement	$139.50	--
Kero-Del	MD		--	$89.95
		Average	$156.57	$74.31
		Half of Cost of Oil Equipment + WH Option (2009$)		$152.81

8-B.2.4 Gas-Fired Instantaneous Water Heaters

The analysis assumes that there is an annual maintenance of residential instantaneous water heaters associated mainly with de-liming the heat exchanger.[12] DOE used a distribution of values for the labor hours required to do the deliming: 0.5 hrs. (25 percent of the time); 1.0 hrs (50 percent of the time); 1.5 hrs (25 percent of the time).[12, 13] DOE assumes that 75 percent of installations will require this and that of those installations 75 percent will be done by a contractor. The average total cost is $105 per year and is applicable to 56 percent of installations.

Table 8-B.2.6 Gas-Fired Instantaneous Water Heater Heat Exchanger De-liming

Description	Crew	Person-Hours	Bare Costs *(2009$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	0.00	23.35	0.00	23.35	35.05
De-liming	1 PLUM	1.0	0.00	46.70	0.00	46.70	70.10
Total		1.5	0.00	70.05	0.00	70.05	**105.15**

* 1 PLUM means a crew of 1 plumber.

8-B.2.5 Direct Heating Equipment

For direct heating equipment, DOE used the maintenance cost data from the 2007 Furnace/Boiler rulemaking.[14] The costs were derived from a 1994 Gas Research Institute (GRI)

report based on field survey sponsored by several gas utilities that repair and service furnace and boiler equipment.[15] The survey estimated the average cost per service call as the average total service charge (parts, labor, and other charges). The average total service charge is $222. DOE used a maintenance frequency of once every five years for all DHE product classes. (See Table 8-B.2.7)

Table 8-B.2.7 Data from GRI Report

Description	**Cost** *(1992$)*	**Cost** *(2009$)*
Case 1 (5-years)	$145	$222

8-B.2.6 Gas-Fired Pool Heaters

Most pool owners do not perform any pool heater maintenance except when the heater does not come on. In such situations, the maintenance work includes verifying controls operation, cleaning burners, cleaning heat exchanger, starting the heater, and measuring water temperature rise. In addition, for advanced design pool heaters it also includes measuring combustion differential pressure. DOE estimated that the maintenance occurs every 3 to 6 year (4.5 years on average).[13]

A consultant provided average number of hours for maintenance[16] and RS Means was used to calculate the labor rates.

Table 8-B.2.8 Baseline Pool Heater Maintenance

Description	**Crew**	**Labor Hours**	**Unit**	**Bare Costs** *(2009$)*				**Total incl. O&P**
				Mat.	**Labor**	**Equip.**	**Total**	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	24.38	0.00	24.38	36.66
Measure millivolt signal, clean burners, clean HX, start up heater, check temperature rise	1 PLUM	4.0	Ea.	0.00	195.00	0.00	195.00	293.28
Total		4.5	Ea.	0.00	219.38	0.00	219.38	**329.94**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.2.9 Advanced Design Pool Heater Maintenance

Description	**Crew**	**Labor Hours**	**Unit**	**Bare Costs** *(2009$)*				**Total incl. O&P**
				Mat.	**Labor**	**Equip.**	**Total**	
Trip Charge	1 PLUM*	1.0	Ea.	0.00	24.38	0.00	24.38	36.66
Measure ignition signal, clean burners, clean HX, measure combustion differential pressure, start up heater, check temperature rise	1 PLUM	6.0	Ea.	0.00	292.50	0.00	292.50	439.92
Total		7.0	Ea.	0.00	316.88	0.00	316.88	**476.58**

* 1 PLUM means a crew of 1 plumber.

8-B.3 REPAIR COSTS

The repair cost reflects the cost to the consumer for a service call when the product fails. In some cases, if the equipment fails residential consumers tend to replace the equipment rather than having them serviced. This is especially true for water heaters. However, there are design options considered for which the components may encounter repair costs during the lifetime of the equipment.

Components most likely to be repaired include the ignition system, gas valve, circulating or combustion blower, electronics/controls/switches, vent system components, and heat exchangers.[11, 13] DOE analyzed the repair costs of ignition systems, circulating blowers, and combustion blowers, as well as the cost of the compressor and evaporator fan components for the heat pump water heater design option.

RS Means and consultants provided the average number of hours for labor and materials costs. RS Means was also used to calculate the labor rates.

8-B.3.1 Component Repair Cost Calculations

Table 8-B.3.1 shows the components most likely to be repaired for each product, as well as cost information and source.

Table 8-B.3.1 Summary of Repair Component Cost Data

Component	Products Used	Material Cost Information	
		Cost *(2009$)*	**Source**
Pilot Ignition (Standing Pilot)	Gas Storage and Instantaneous Water Heaters, DHE (All)	$36	Average value from internet survey[17, 18, 19, 20]
Pilot Ignition (Millivolt)	Pool Heaters	$20	Consultant PH Report[16]
Electronic Ignition (IID or Direct Spark)	Gas (Instantaneous) Water Heaters, Pool Heaters, DHE (All)	$42*	Average value from internet survey[21, 22, 23]
Electronic Ignition (Hot Surface Ignition)	Gas (Storage) Water Heaters		
Combustion Fan (Power Vent or Induced Draft)	Gas Storage and Instantaneous Water Heaters, Pool Heaters, DHE (All),	$110*	Average Value from Consultant WH Report[4]
Main Circulating Air Blower Motor	DHE (Gas Wall Fan, Gas Floor, Gas Room)		
Electric Resistance Heating Element	Electric Water Heaters	$16	Consultant Report
Heat Pump Compressor Component	Electric Water Heaters	$110	Average value from internet survey**[24, 25, 26]
Heat Pump Evaporator Fan Component	Electric Water Heaters	$18	Average value from internet survey[27]

* For pool heaters electronic ignition cost is $50 and combustion fan is $175 from consultant report.[16].
** Prices for Embraco Compressor (model #FF10HBK), which was used in ECR WatterSaver model.

8-B.3.1.1 Pilot Ignition Repair Cost

Table 8-B.3.2 shows the repair cost for pilot light ignition (standing pilot) for gas-fired storage water heaters, Table 8-B.3.3 shows the repair cost for pilot light ignition (standing pilot) for gas-fired instantaneous water heaters, Table 8-B.3.4 shows the repair cost for pilot light ignition (standing pilot) for direct heating equipment, and Table 8-B.3.5 shows the repair cost for pilot light ignition (millivolt) for pool heaters.

Table 8-B.3.2 Pilot Light Ignition (Standing Pilot) Repair Cost for Gas-fired Storage Water Heaters

Description	Crew	Labor Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	24.68	0.00	24.68	37.04
Repair Pilot Light Ignition	1 PLUM	2.0	Ea.	58.87	98.70	0.00	157.57	212.91
Total		2.5		58.87	123.38	0.00	182.25	**249.94**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.3 Pilot Light Ignition (Standing Pilot) Repair Cost for Gas-fired Instantaneous Water Heaters

Description	Crew	Labor Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.50	Ea.	0.00	23.35	0.00	23.35	35.05
Repair Pilot Light Ignition	1 PLUM	1.25	Ea.	35.74	58.38	0.00	94.12	126.94
Total		1.75		35.74	81.73	0.00	117.47	**161.99**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.4 Pilot Light Ignition (Standing Pilot) Repair Cost for Direct Heating Equipment

Description	Crew	Labor Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 ELEC	0.50	Ea.	0.00	23.50	0.00	23.50	34.97
Repair Pilot Device	1 ELEC	1.25	Ea.	35.74	58.75	0.00	94.49	126.73
Total		1.75		35.74	82.25	0.00	117.99	**161.70**

* 1 ELEC means a crew of 1 electrician.

Table 8-B.3.5 Pilot Light Ignition (Millivolt) Repair Cost for Pool Heaters

Description	Crew	Labor Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.50	Ea.	0.00	24.38	0.00	24.38	36.66
Repair Pilot Light Ignition	1 PLUM	1.25	Ea.	20.00	60.94	0.00	80.94	113.65
Total		1.75		20.00	85.31	0.00	105.31	**150.31**

* 1 PLUM means a crew of 1 plumber.

8-B.3.1.2 Electronic Ignition Repair Cost

Table 8-B.3.6 shows the repair cost for electronic ignition for gas-fired storage water heaters, Table 8-B.3.7 shows the repair cost for electronic ignition for gas-fired instantaneous water heaters, Table 8-B.3.8 shows the repair cost for electronic ignition for direct heating equipment, and Table 8-B.3.9 shows the repair cost for electronic ignition for pool heaters.

Table 8-B.3.6 Electronic Ignition Repair Cost for Gas-fired Storage Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	24.68	0.00	24.68	37.04
Repair Electronic Ignition	1 PLUM	2.0	Ea.	104.00	98.70	0.00	202.70	262.55
Total		2.5		104.00	123.38	0.00	227.38	**299.59**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.7 Electronic Ignition Repair Cost for Gas-fired Instantaneous Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.50	Ea.	0.00	23.35	0.00	23.35	35.05
Repair Electronic Ignition	1 PLUM	1.75	Ea.	42.21	81.73	0.00	123.94	169.10
Total		2.25		42.21	105.08	0.00	147.29	**204.15**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.8 Electronic Ignition Repair Cost for Direct Heating Equipment

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 ELEC*	0.50	Ea.	0.00	23.50	0.00	23.50	34.97
Repair Electronic Ignition	1 ELEC	1.75	Ea.	42.21	82.25	0.00	124.46	168.82
Total		2.25		42.21	105.75	0.00	147.96	**203.79**

* 1 ELEC means a crew of 1 electrician.

Table 8-B.3.9 Electronic Ignition Repair Cost for Pool Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.50	Ea.	0.00	24.38	0.00	24.38	36.66
Repair Electronic Ignition	1 PLUM	1.75	Ea.	50.00	85.31	0.00	135.31	183.31
Total		2.25		50.00	109.69	0.00	159.69	**219.97**

* 1 PLUM means a crew of 1 plumber.

8-B.3.1.3 Heating Element Repair Cost

The repair cost of the electric water heater includes the cost of replacing the heating element. Based on available information, DOE estimated that the heating element fails on average in the 5th year of operation[a] for 20 percent of the households.[3] The estimated average heating element repair cost is $105 (see Table 8-B.3.10).

Table 8-B.3.10 Heating Element Repair Cost for Electric Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	23.35	0.00	23.35	35.05
Replace Heating Element	1 PLUM	1.0	Ea.	0.00	46.70	0.00	46.70	70.10
Total		1.5		0.00	70.05	0.00	70.05	**105.15**

* 1 PLUM means a crew of 1 plumber.

8-B.3.1.4 Power Vent/Induced Draft Fan Repair Cost

Table 8-B.3.11 shows the repair cost for a power vent fan for gas-fired storage water heaters, Table 8-B.3.12 shows the repair cost for a power vent fan for gas-fired instantaneous water heaters, Table 8-B.3.13 shows the repair cost for a fan for direct heating equipment, and Table 8-B.3.14 shows the repair cost for a power vent fan for pool heaters.

Table 8-B.3.11 Power Vent Fan Repair Cost for Gas-fired Storage Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	24.68	0.00	24.68	37.04
Repair Blower Assembly	1 PLUM	2.5	Ea.	165.63	123.38	0.00	289.01	367.38
Total		3.0	Ea.	165.63	148.05	0.00	313.68	**404.42**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.12 Power Vent Fan Repair Cost for Gas-fired Instantaneous Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 ELEC*	0.5	Ea.	0.00	23.50	0.00	23.50	34.97
Repair Blower Assembly	1 ELEC	2.0	Ea.	110.00	94.00	0.00	204.00	260.87
Total		2.5	Ea.	110.00	117.50	0.00	227.50	**295.84**

* 1 ELEC means a crew of 1 electrician.

[a] DOE used a triangular distribution with a mean of 5 years and a maximum of 9 and minimum of 1 year.

Table 8-B.3.13 Fan Repair Cost for Direct Heating Equipment

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	23.35	0.00	23.35	35.05
Repair Blower Assembly	1 PLUM	2.0	Ea.	110.00	93.40	0.00	203.40	261.19
Total		2.5	Ea.	110.00	116.75	0.00	226.75	**296.24**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.14 Power Vent Fan Repair Cost for Pool Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	24.38	0.00	24.38	36.66
Repair Power Vent Fan	1 PLUM	2.0	Ea.	250.00	97.50	0.00	347.50	421.64
Total		2.5	Ea.	250.00	121.88	0.00	371.88	**458.30**

* 1 PLUM means a crew of 1 plumber.

8-B.3.1.5 Heat Pump Water Heater Repair Cost

The repair cost of the heat pump water heater represents the cost of replacing the compressor and the evaporator fan. Table 8-B.3.15 shows the repair cost for the compressor and Table 8-B.3.16 shows the repair cost for the evaporator fan.

Table 8-B.3.15 Heat Pump Compressor Repair Cost for Electric Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	23.35	0.00	23.35	35.05
Repair Compressor	1 PLUM	1.0	Ea.	167.88	46.70	0.00	214.58	254.76
Total		1.5	Ea.	167.88	70.05	0.00	237.93	**289.81**

* 1 PLUM means a crew of 1 plumber.

Table 8-B.3.16 Heat Pump Evaporator Fan Cost for Electric Water Heaters

Description	Crew	Person-Hours	Unit	Bare Costs *(2009$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	Ea.	0.00	23.35	0.00	23.35	35.05
Repair Evaporator Fan	1 PLUM	1.0	Ea.	18.49	46.70	0.00	65.19	90.44
Total		1.5	Ea.	18.49	70.05	0.00	88.54	**125.49**

* 1 PLUM means a crew of 1 plumber.

8-B.3.2 Lifetime Distributions for Repair Costs

DOE determined the lifetime of the different product components from several sources. Table 8-B.3.17 lists the gathered lifetime data and the data sources.

Table 8-B.3.17 Component Lifetime Data Gathered

Component	Mean (Median) Lifetime	Data Source	Reference
Standing Pilot Ignition System (Boiler)	9.1 (8.0)	survey	1994 GRI Report[15]
Standing Pilot Ignition System (Furnace)	8.1 (8.0)	survey	1994 GRI Report
Standing Pilot thermocouple	10.2	survey	1993 TSD[11]
Intermittent Ignition (IID)	14	estimate	1993 TSD
IID Electronic Ignition (Boiler)	10.1 (10.0)	survey	1994 GRI Report
IID Electronic Ignition (Furnace)	8.8 (10.0)	survey	1994 GRI Report
Direct Spark Ignition (Boiler)	13.2 (15.0)	survey	1994 GRI Report
Direct Spark Ignition (Furnace)	10.3 (10.0)	survey	1994 GRI Report
Hot Surface Ignitor (Boiler)	16.1 (20.0)	survey	1994 GRI Report
Hot Surface Ignitor (Furnace)	4.6 (6.0)	survey	1994 GRI Report
Ignition (pool heaters)	5.0	estimate	Consultant[16]
Main Circulating Air Blower Motor (Boiler)	14.2 (10.0)	survey	1994 GRI Report
Main Circulating Air Blower Motor (Furnace)	11.4 (12.0)	survey	1994 GRI Report
Induced Draft – Non-Condensing(Boiler)	16.2 (15.0)	survey	1994 GRI Report
Induced Draft - Condensing(Boiler)	22.6 (15.0)	survey	1994 GRI Report
Induced Draft – Non-Condensing(Furnace)	14.8 (15.0)	survey	1994 GRI Report
Induced Draft - Condensing(Furnace)	13.8 (15.0)	survey	1994 GRI Report
Combustion Fan	11.1	survey	1993 TSD
Electric Resistance Heating Element	5	estimate	Consultant
Electronics/Controls/Switches (Boiler)	10.0 (10.0)	survey	1994 GRI Report
Electronics/Controls/Switches (Furnace)	8.7 (10.0)	survey	1994 GRI Report
Gas Valves (Boiler)	14.9 (15.0)	survey	1994 GRI Report
Gas Valves (Furnace)	14.0 (15.0)	survey	1994 GRI Report
Heat Pump Compressor	19	estimate	Based on average Refrigerator lifetime [28, 29]
Heat Pump Evaporator Fan	19	estimate	

DOE used the lifetimes in Table 8-B.3.18 for each component analyzed.

Table 8-B.3.18 Mean Component Lifetime Used in Analysis

Component	Mean Lifetime *(years)*	Products Used
Pilot Ignition (Standing Pilot)	10	Gas (Storage) Water Heater, Gas (Instantaneous) WH, DHE (All)
Pilot Ignition	5	Pool Heaters
Electric Resistance Heating Element	5	Electric Water Heaters
Electronic Ignition (IID or Direct Spark)	12	Gas (Instantaneous) WH, Pool Heater, DHE (All)
Electronic Ignition (Hot Surface Ignition)	15	Gas (Storage) Water Heater
Combustion Fan (Power Vent or Induced Draft)	15	Gas (Storage) Water Heater, Gas (Instantaneous) WH, Pool Heaters, DHE (All)
Main Circulating Air Blower Motor	12	DHE (FWF, FF, RH)
Heat Pump Compressor	19	Electric Water Heaters
Heat Pump Evaporator Fan	19	Electric Water Heaters

Table 8-B.3.19 shows the average, minimum and maximum lifetime, as well as the maximum percentile values used to determine the parameters for Weibull distributions. See appendix 8-C for more information about the derivation of the Weibull distribution parameters. DOE setup the maximum percentile used in the analysis at 99 percent.

Table 8-B.3.19 Parameters for Generating Weibull Distributions for Different Component Lifetimes

Component Failure Year	Expert Opinion Values				Weibull Parameters	
	Minimum *(years)*	Average *(years)*	Maximum *(years)*	Maximum percentile *(%)*	Alpha (scale)	Beta (shape)
5 Year	0	5	10	99	5.6257	2.6548
10 Year	0	10	20	99	11.2513	2.6548
12 Year	0	12	24	99	13.5016	2.6548
15 Year	0	15	30	99	16.8770	2.6548
19 Year	0	19	38	99	21.3775	2.6548

Figure 8-B.3.1 to Figure 8-B.3.8 show the Weibull distribution as well as the cumulative Weibull distribution for each water heater type.

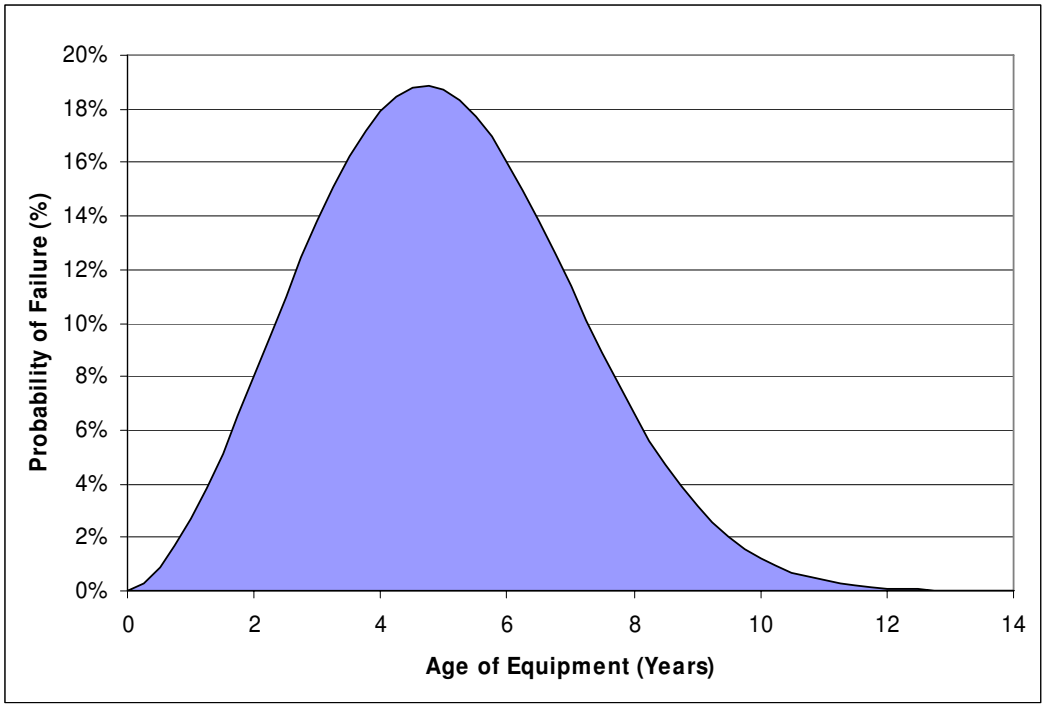

Figure 8-B.3.1 Fraction of the Components with 5-Year Lifetime Failing

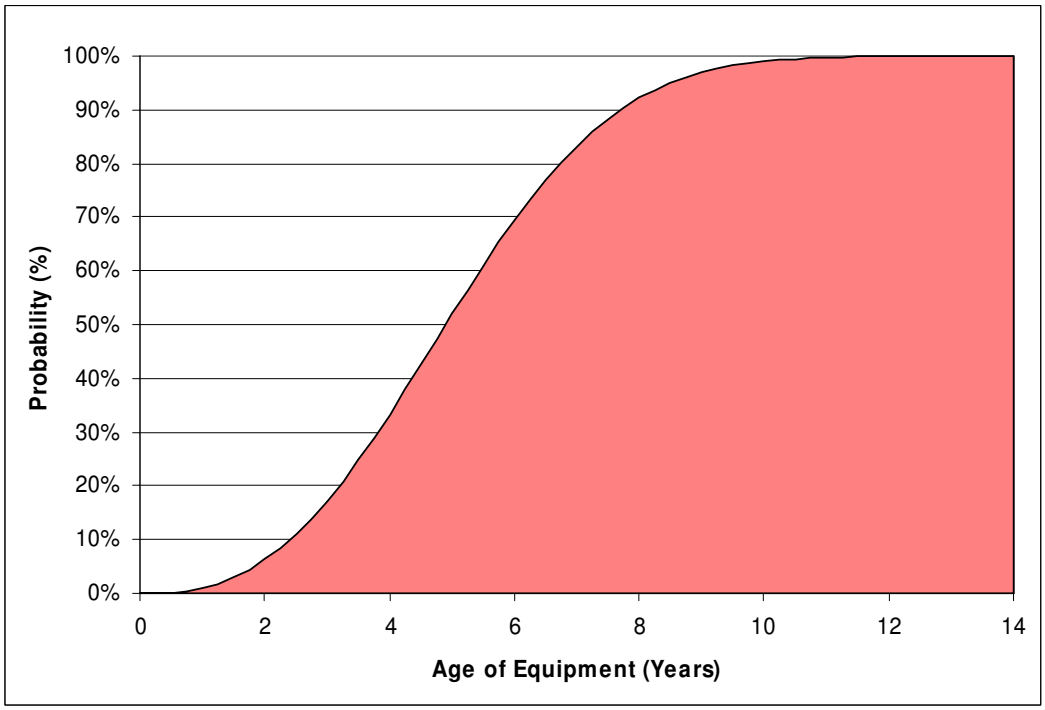

Figure 8-B.3.2 Cumulative Lifetime Length of Components with 5-Year Lifetime

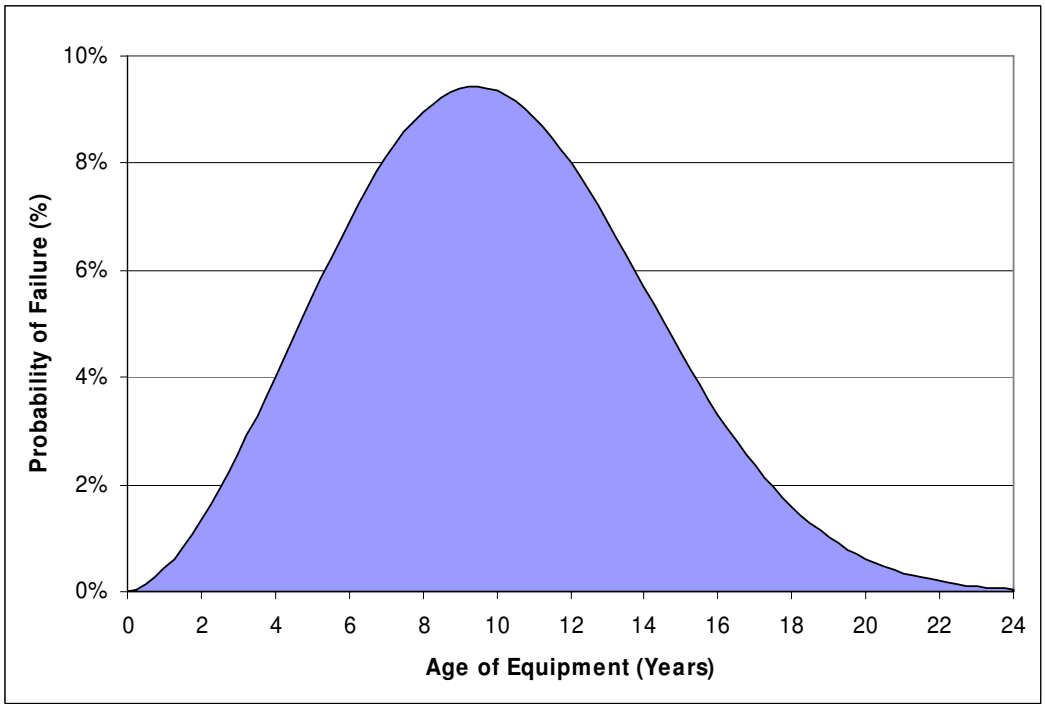

Figure 8-B.3.3 Fraction of the Components with 10-Year Lifetime Failing

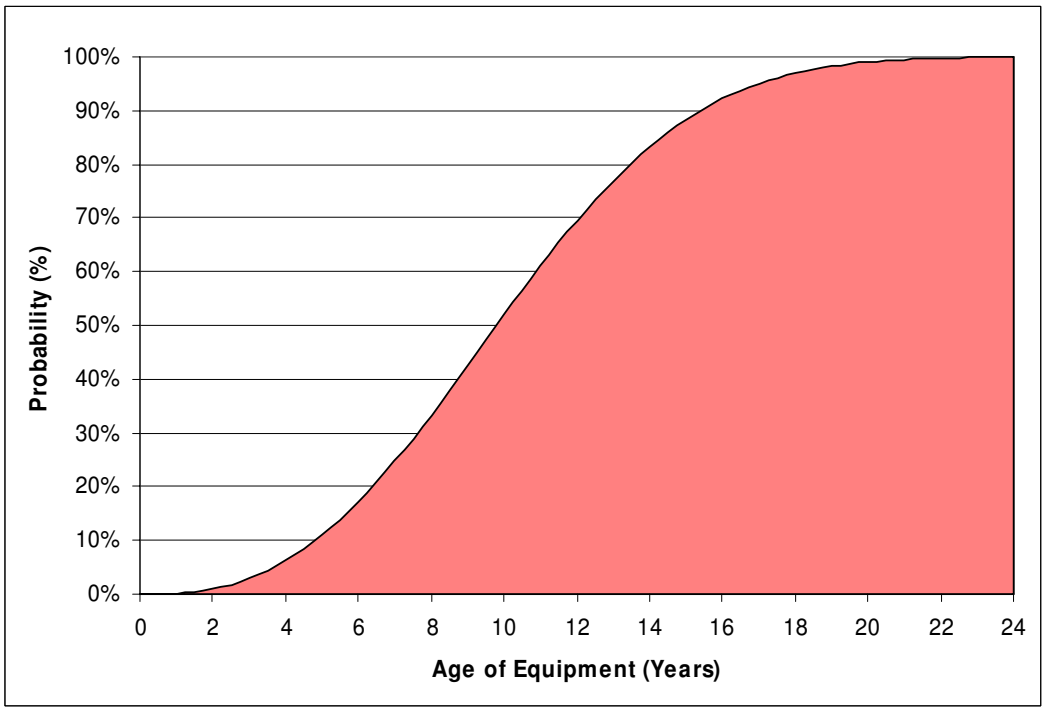

Figure 8-B.3.4 Cumulative Lifetime Length of Components with 10-Year Lifetime

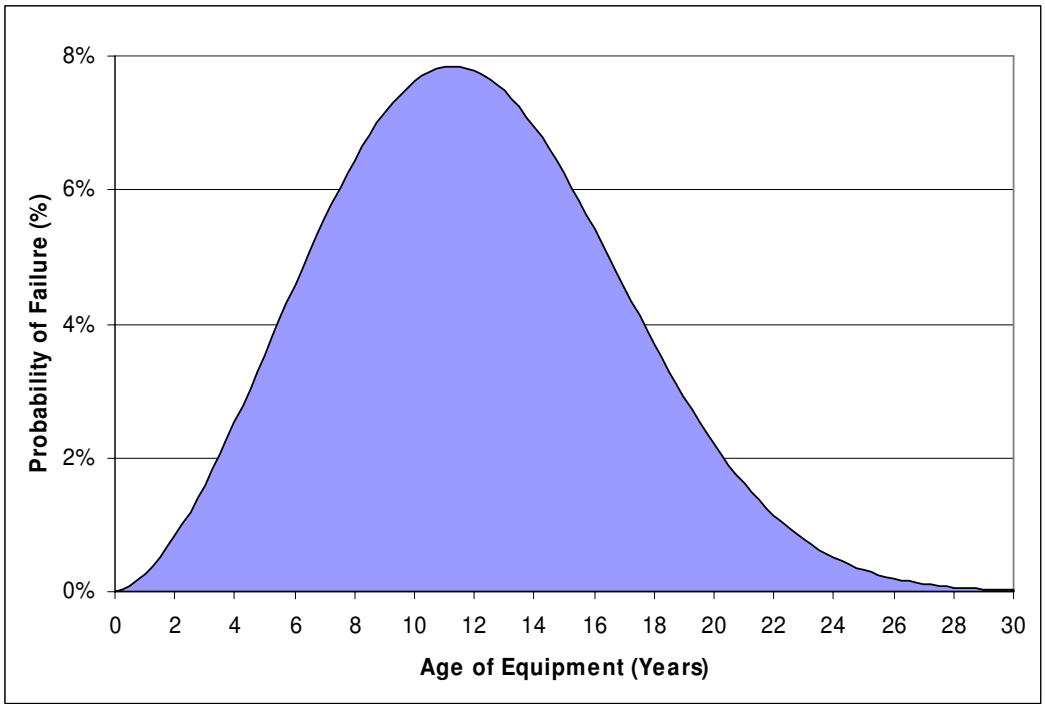

Figure 8-B.3.5 Fraction of the Components with 12-Year Lifetime Failing

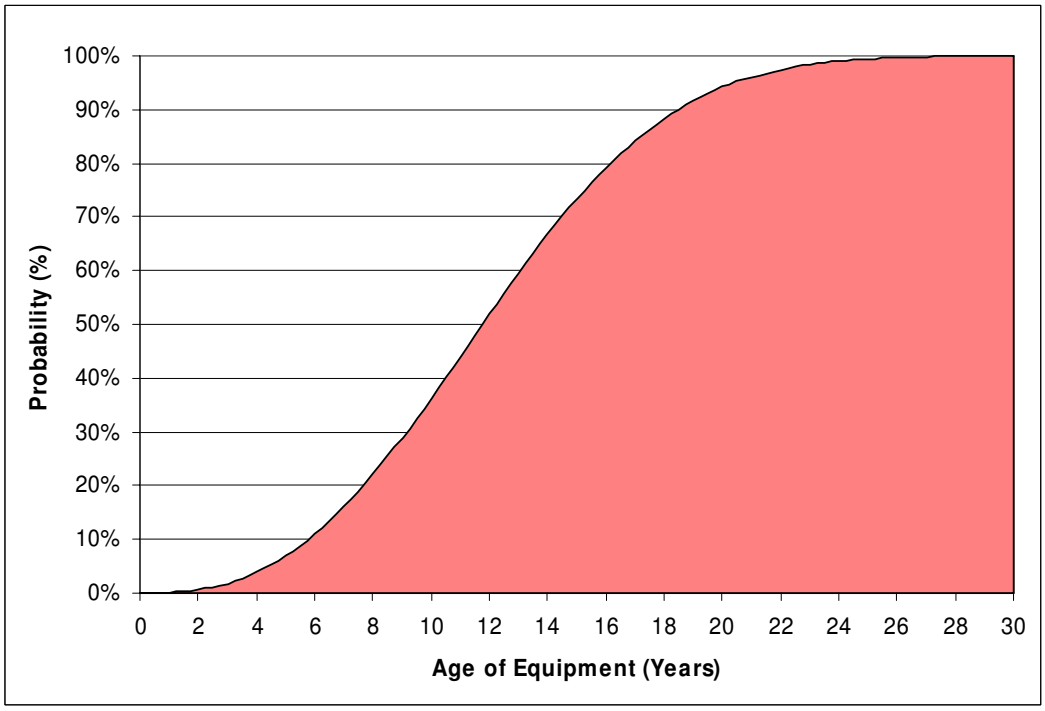

Figure 8-B.3.6 Cumulative Lifetime Length of Components with 12-Year Lifetime

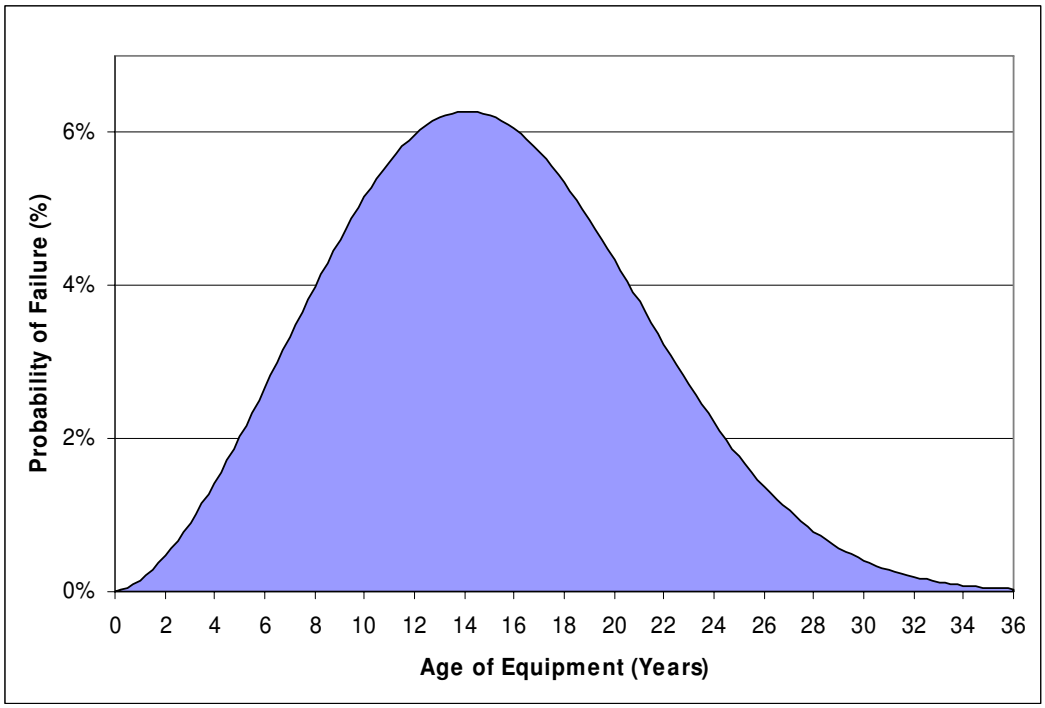

Figure 8-B.3.7 Fraction of the Components with 15-Year Lifetime Failing

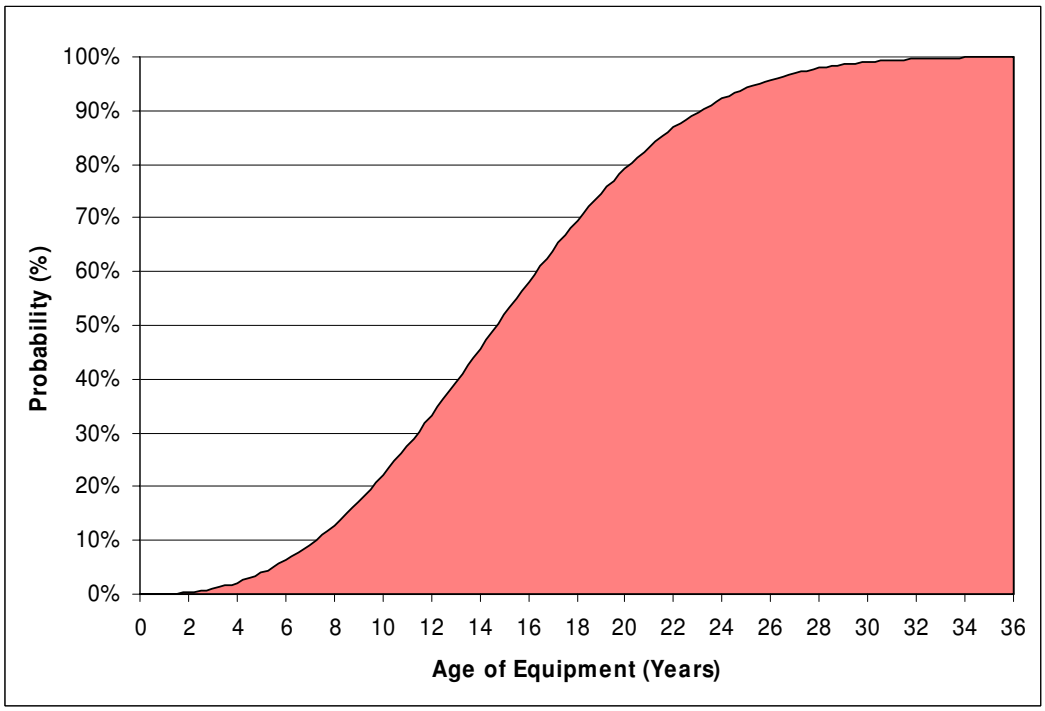

Figure 8-B.3.8 Cumulative Lifetime Length of Components with 15-Year Lifetime

8-B.3.3 Equipment Lifetime versus Component Lifetime Correlations

Equipment lifetime and component lifetime are not independent variables. Often once the component fails the equipment is not repaired and it represents the end of the equipment life. Therefore a correlation variable must be applied in order to account for this. The correlation factor is presented as the fraction total failures calculated by simple using the component lifetime and equipment lifetime which are actual failures. For example, the failure rate calculated for pilot ignition for gas storage water heaters is close to 100%, by applying a 10% correlation factor the failure rate becomes 10.7%. DOE derived correlation variables in order to match available failure rate data from pool heater consultant report,[16] water heater consultant report,[3] and 1994 GRI Report.[15] See figure Table 8-B.3.20 to Table 8-B.3.20 for results.

Table 8-B.3.20 Component Repair Frequency Results for Gas Storage Water Heater

Component	Analysis Values			
	Component Lifetime *(years)*	**Equipment Lifetime** *(years)*	**Correlation Factor** *(%)*	**Failure Rate** *(%)*
Pilot Ignition	12	13	10	10.7
Electronic Ignition	15	13	10	8.4
Power Vent	15	13	10	9.1

Table 8-B.3.21 Component Repair Frequency Results for Electric Storage Water Heater

Component	Analysis Values			
	Component Lifetime *(years)*	**Equipment Lifetime** *(years)*	**Correlation Factor** *(%)*	**Failure Rate** *(%)*
Heating Element	3.0	13.0	20	20.8
HP Compressor	19.0	13.0	50	11.0
HP Evaporation Fan	19.0	13.0	50	10.6

Table 8-B.3.22 Component Repair Frequency Results for Gas-Fired Instantaneous Water Heater

Component	Analysis Values			
	Component Lifetime *(years)*	**Equipment Lifetime** *(years)*	**Correlation Factor** *(%)*	**Failure Rate** *(%)*
Pilot Ignition	10.0	20.0	30	28.9
Electronic Ignition	12.0	20.0	30	27.2
Power Vent	15.0	20.0	30	22.2

Table 8-B.3.23 Component Repair Frequency Results for Direct Heating Equipment

Component	Analysis Values			
	Component Lifetime *(years)*	**Equipment Lifetime** *(years)*	**Correlation Factor** *(%)*	**Failure Rate** *(%)*
Pilot Ignition	10.0	15.0	30	25.2
Electronic Ignition	10.0	15.0	30	24.2
Air Circulation	12.0	15.0	30	19.6
Power Vent	15.0	15.0	30	14.1

Table 8-B.3.24 Component Repair Frequency Results for Pool Heaters

Component	Analysis Values			
	Component Lifetime *(years)*	**Equipment Lifetime** *(years)*	**Correlation Factor** *(%)*	**Failure Rate** *(%)*
Pilot Ignition	5	10	50	41.2
Electronic Ignition	12	10	50	8.7
Induced Draft	15	10	50	5.9

8-B.3.4 Repair Cost Methodology Flowcharts by Product Type

Figure 8-B.3.9 to Figure 8-B.3.13 provide the repair cost methodology flowcharts for each product type.

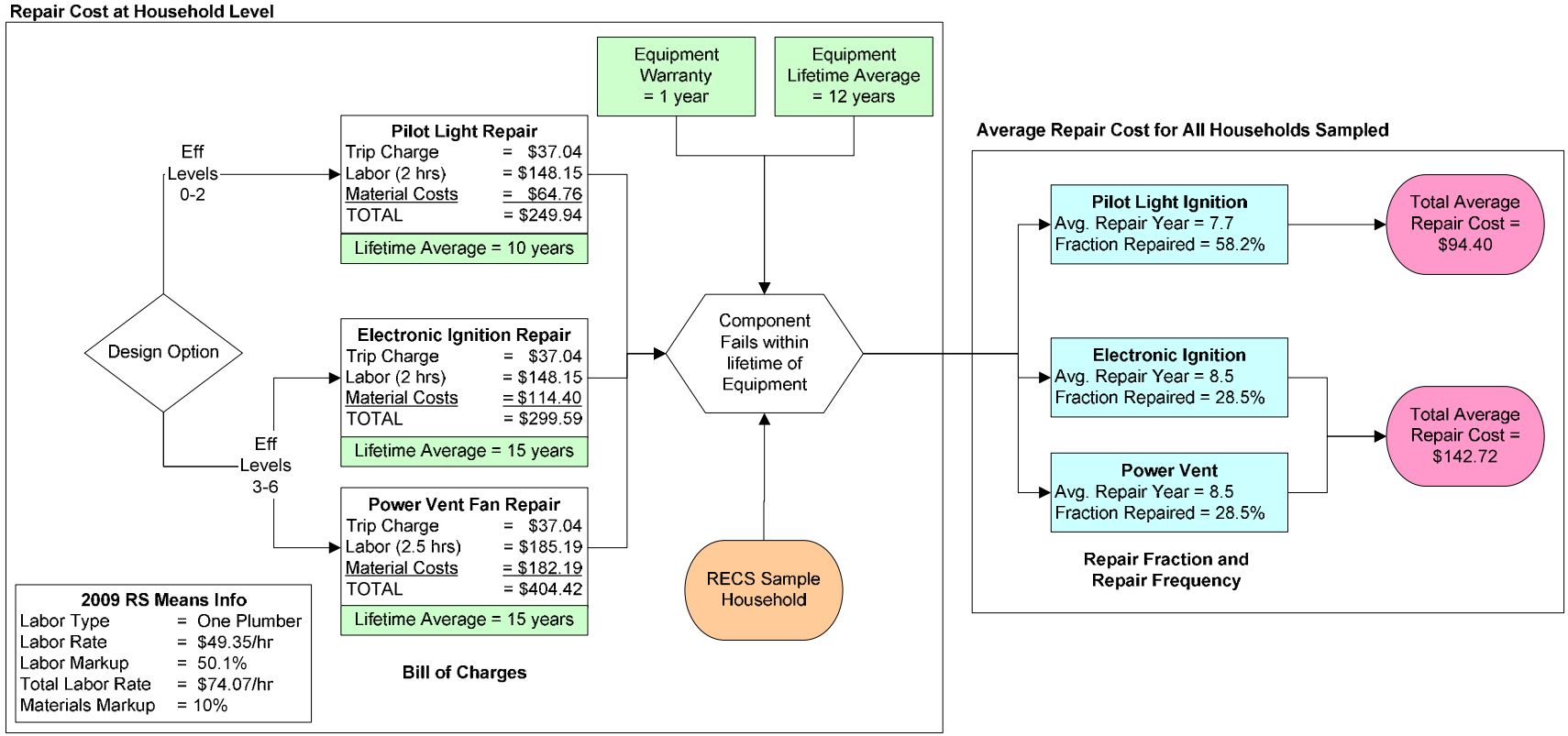

Figure 8-B.3.9 Methodology for Calculating Repair Cost for Gas-Fired Storage Water Heaters

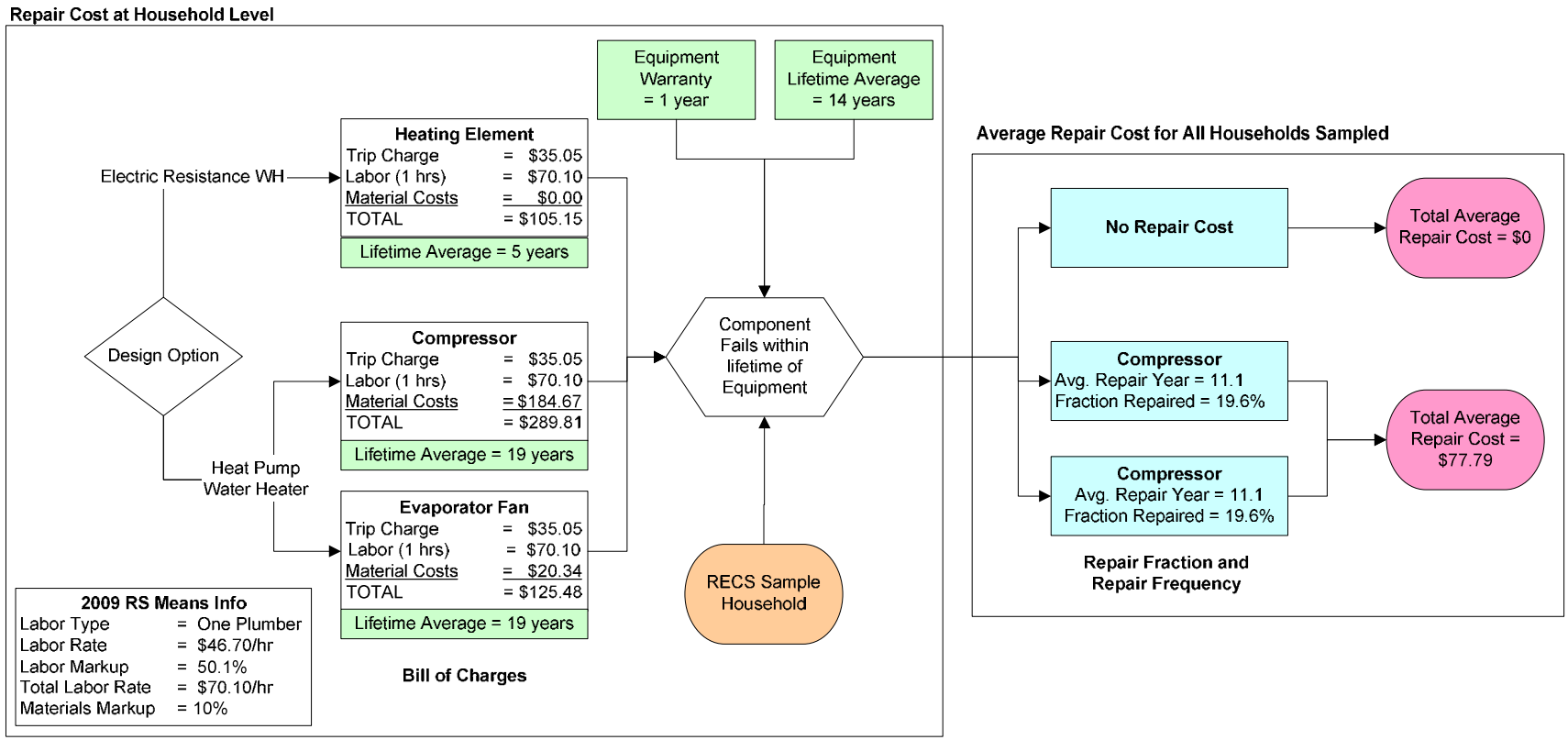

Figure 8-B.3.10 Methodology for Calculating Repair Cost for Electric Storage Water Heaters

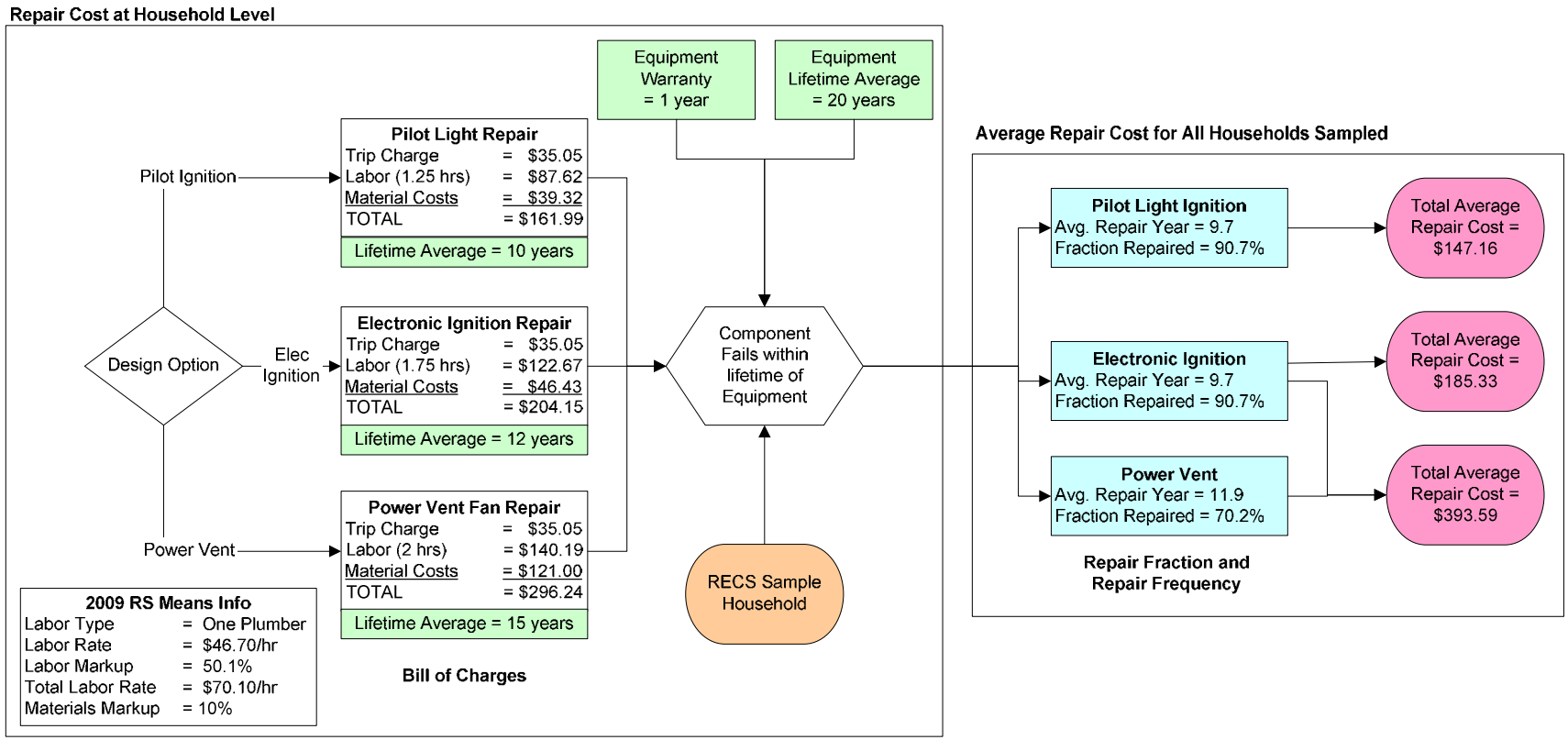

Figure 8-B.3.11 Methodology for Calculating Repair Cost for Gas-Fired Instantaneous Water Heaters

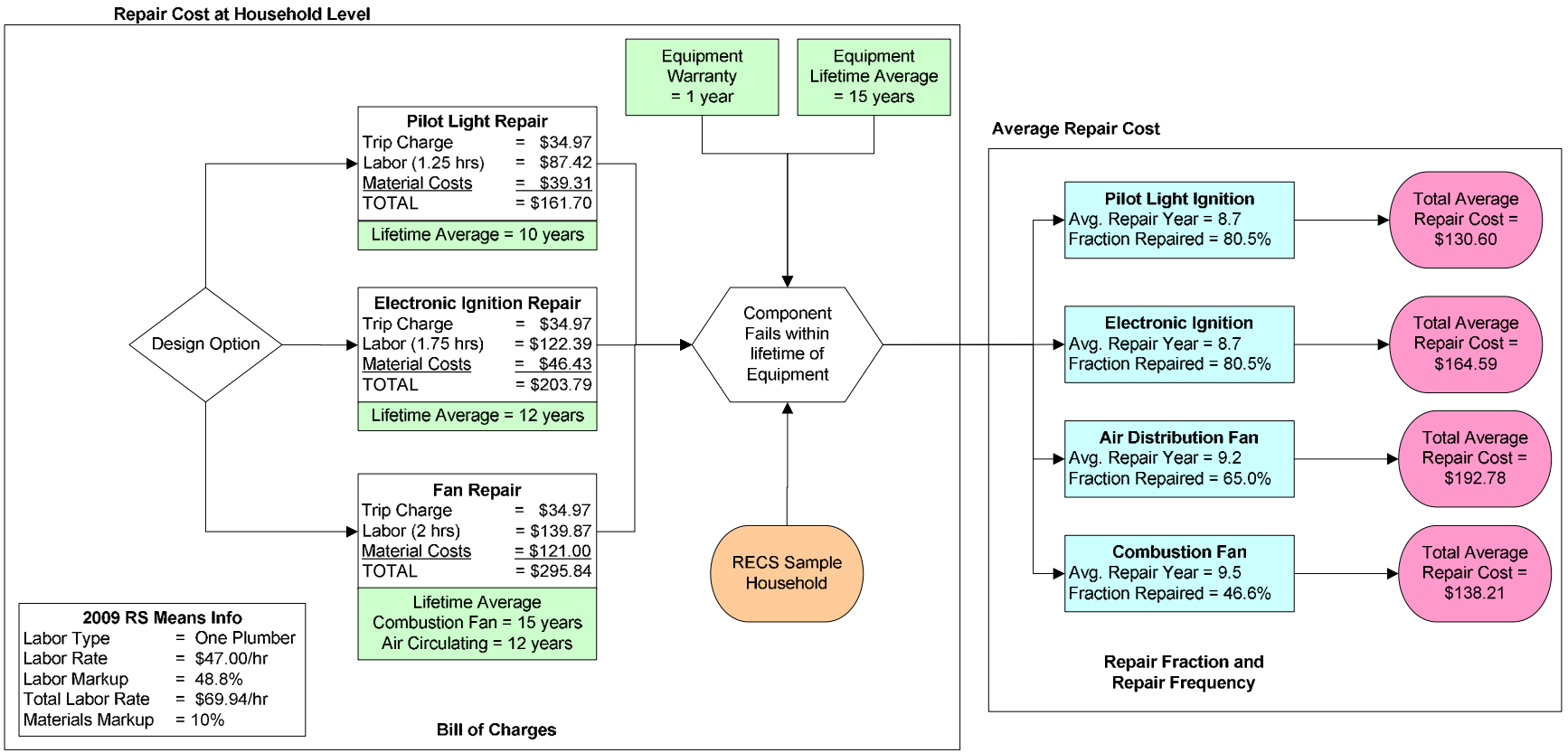

Figure 8-B.3.12 Methodology for Calculating Repair Cost for Direct Heating Equipment

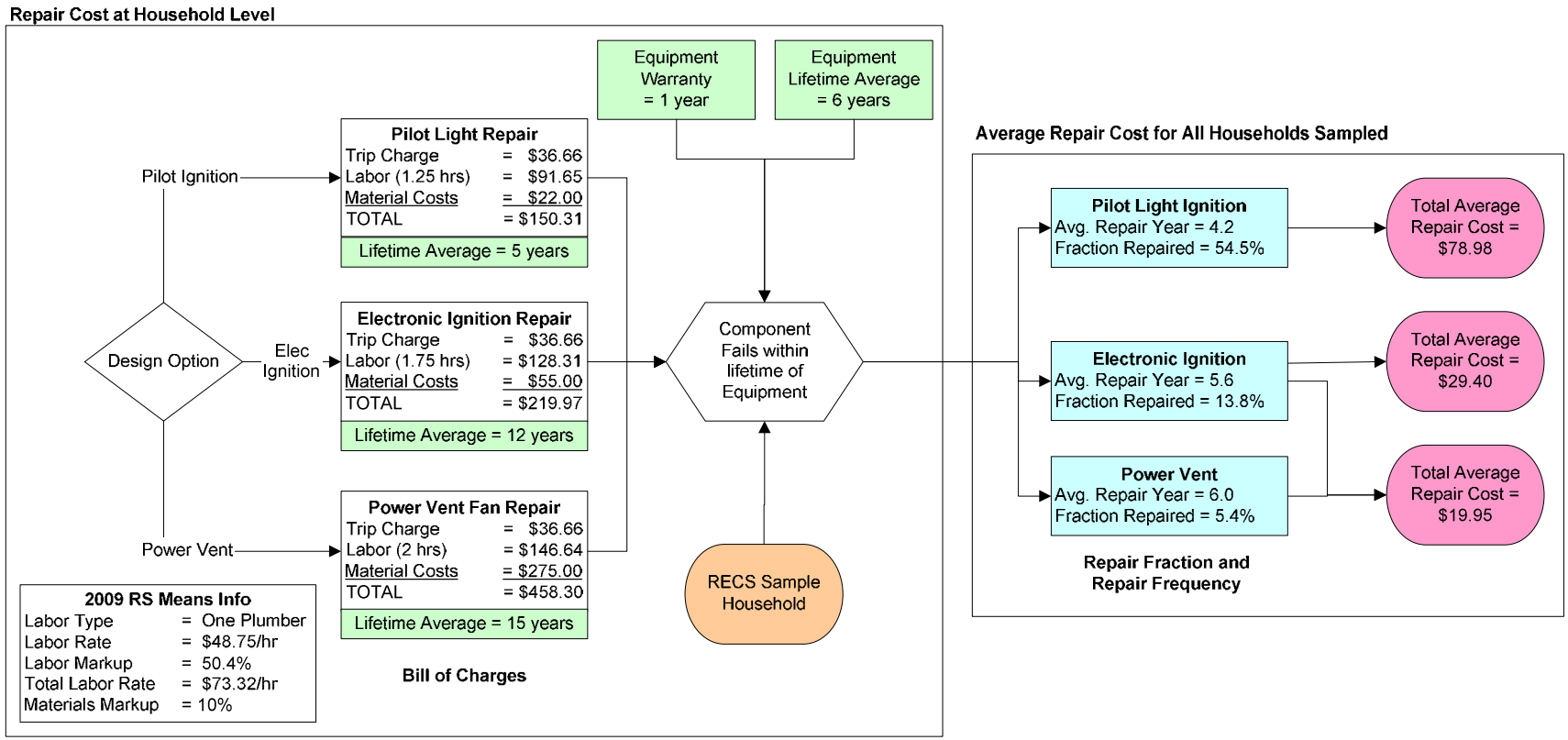

Figure 8-B.3.13 Methodology for Calculating Repair Cost for Pool Heaters

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